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COVER SHEET
Access 5 Project Deliverable

Deliverable Number: *HSI013*

Title: *Step 1: Human System Integration Pilot-Technology Interface Requirements for Collision Avoidance*

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Abstract:
This document provides definition of technology human interface requirements for Collision Avoidance (CA). This was performed through a review of CA-related, HSI requirements documents, standards, and recommended practices. Technology concepts in use by the Access 5 CA work package were considered... Beginning with the HSI high-level functional requirement for CA, and CA technology elements, HSI requirements for the interface to the pilot were identified. Results of the analysis describe (1) the information required by the pilot to have knowledge CA system status, and (2) the control capability needed by the pilot to obtain CA information and affect an avoidance maneuver. Fundamentally, these requirements provide the candidate CA technology concepts with the necessary human-related elements to make them compatible with human capabilities and limitations. The results of the analysis describe how CA operations and functions should interface with the pilot to provide the necessary CA functionality to the UA-pilot system .Requirements and guidelines for CA are partitioned into four categories: (1) General, (2) Alerting, (3) Guidance, and (4) Cockpit Display of Traffic Information. Each requirement is stated and is supported with a rationale and associated reference(s).

Status:

Document Status Work in Progress

Limitations on use:
This document is an interim deliverable. It represents the Human Systems Integration functions and performance requirements limited to enroute operations above FL430. Operations below FL430 and terminal operations have not been addressed in this document.

Step 1: Human System Integration (HSI) FY05 Pilot-Technology Interface Requirements for Collision Avoidance

Access 5
Technology Integrated Product Team
Human Systems Integration

August 31, 2005

The following document was prepared by a collaborative team through the noted work package. This was a funded effort under the Access 5 Project.

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Executive Summary

Access 5 is a NASA-led project tasked to recommend the policies, procedures, and functional requirements that will ensure High Altitude Long-Endurance (HALE) Unmanned Aircraft Systems (UAS) operate as safely as other routine users of the National Airspace System (NAS). Four phases or "STEPS" are planned to systematically develop the necessary technology, policies and regulations to enable manufacturers to apply for Federal Aviation Administration (FAA) certification and approval needed to operate their civil UAS in the NAS. Current (FY05) effort limits focus to UASs that operate above 43,000 feet (STEP 1).

In order for UAS to be integrated into the NAS, it is necessary to identify the human systems integration requirements that ensure safe operations in the NAS. As a result, the Human System Integration (HSI) Work Package was established within the overall Access 5 program to address this objective. In FY05, several HSI products were developed to contribute to overall program objectives.

This product involves definition of technology interface requirements for Collision Avoidance (CA). This was performed through a review of CA-related, HSI requirements documents, standards, and recommended practices. Technology concepts in use by the CA WP were assessed also.

Technology concepts in use by the CA WP were assessed.

Beginning with the HSI high-level functional requirement for CA, and CA technology elements, HSI requirements for the interface to the pilot were identified. Results of the analysis describe (1) the information required by the pilot to have knowledge CA system status, and (2) the control capability needed by the pilot to obtain CA information and affect an avoidance maneuver. Fundamentally, these requirements provide the candidate CA technology concepts with the necessary human-related elements to make them compatible with human capabilities and limitations. The results of the analysis describe how CA operations and functions should interface with the pilot to provide the necessary CA functionality to the UA-pilot system.

Requirements and guidelines for CA are partitioned into four categories: (1) General, (2) Alerting, (3) Guidance, and (4) Cockpit Display of Traffic Information.

Each requirement is stated and is supported with a rationale and associated reference(s).

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Acronym List

ARD	Aerospace Resource Document
ARP	Aerospace Recommended Practice
ATC	Air Traffic Control
ARTCC	Air Route Traffic Control Center
ACS	Aircraft Control Station
BLOS	Beyond Line of Sight
C2	Command and Control
CA	Collision Avoidance
ELOS	Equivalent Level of Safety
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FL	Flight Level
FRD	Functional Requirements Document
HALE	High Altitude, Long Endurance
HSI	Human System Integration
IFR	Instrument Flight Rules
LOS	Line of Sight
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NMAC	Near Mid Air Collision
RA	Resolution Advisory
RVSM	Reduced Vertical Separation Minima
SAE	Society of Automotive Engineers
TCAS	Traffic Alert and Collision Avoidance System
UA	Unmanned Aircraft
VFR	Visual Flight Rules
WP	Work Package

1. Introduction

1.1. Background

Access 5 is a NASA-led project tasked to recommend the policies, procedures, and functional requirements that will ensure High Altitude Long-Endurance (HALE) Unmanned Aircraft Systems (UAS) operate as safely as other routine users of the National Airspace System (NAS). Four phases or "STEPS" are planned to systematically develop the necessary technology, policies and regulations to enable manufacturers to apply for Federal Aviation Administration (FAA) certification and approval needed to operate their civil UAS in the NAS. Current (FY05) effort limits focus to UASs that operate above 43,000 feet (STEP 1).

In order for UAS to be integrated into the NAS, it is necessary to identify the human systems integration requirements that ensure safe operations in the NAS. As a result, the Human System Integration (HSI) Work Package was established within the overall Access 5 program to address this objective. In FY05, several HSI products were developed to contribute to overall program objectives. The FY05 HSI effort followed a standard, HSI process methodology that produced the following deliverables (Figure 1):

Deliverable 1: Human System Integration Step 1 Functional Requirement Document (FRD)

Deliverable 2: Human System Integration (HSI) Step 1 Design Guidelines for the Unmanned Aircraft System (UAS) Ground Control Station

Deliverable 3: High Altitude Long Endurance (HALE) Unmanned Aircraft System (UAS) Pilot Rating Criteria (Draft)

Deliverable 4: HSI Requirements and Guidelines for Experimental Certification of the Unmanned Aircraft System

Deliverable 5: Human Systems Integration Step 1 Pilot-Technology Interface Requirements

Deliverable 5a: Human Systems Integration Step 1 Pilot-Technology Interface Requirements for Command, Control, and Communications (C3) in Unmanned Aircraft Systems

Deliverable 5b: Human Systems Integration Step 1 Pilot-Technology Interface Requirements for Collision Avoidance in Unmanned Aircraft Systems

Deliverable 5c: Human Systems Integration Step 1 Pilot-Technology Interface Requirements for Contingency Management System in Unmanned Aircraft Systems

Deliverable 5d: Human Systems Integration Step 1 Pilot-Technology Interface Requirements for the Weather System in Unmanned Aircraft Systems

Deliverable 6: Human Systems Integration Support to Simulation and Flight Test for Step 1

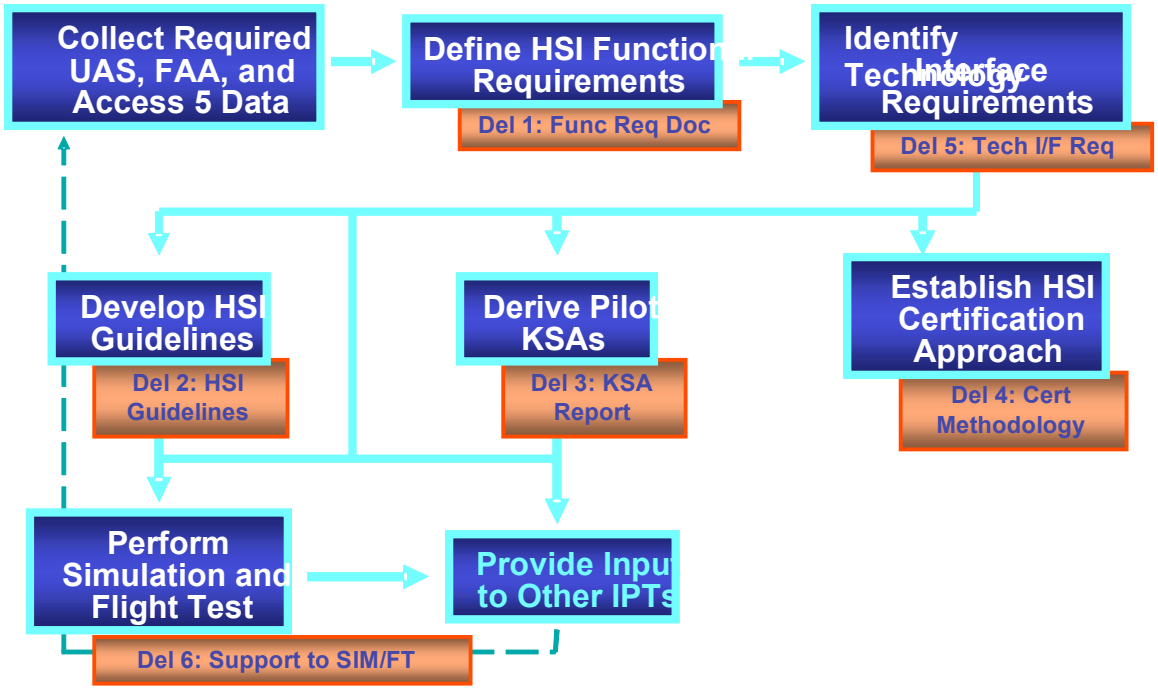

Figure 1. FY05 HSI Process and Deliverable Overview

2. Document Purpose

The purpose of this document is to define HSI technology interface requirements for Collision Avoidance (CA).

Research of human capabilities and limitations known for CA was performed through a review of HSI requirements documents, standards, and recommended practices.

Technology concepts in use by the CA WP were assessed.

Beginning with the HSI high-level functional requirement for CA, and CA technology elements, HSI requirements for the interface to the pilot were identified. Results of the analysis describe (1) the information required by the pilot to have knowledge CA system status, and (2) the control capability needed by the pilot to obtain CA information and affect an avoidance maneuver. Fundamentally, these requirements provide the candidate CA technology concepts with the necessary human-related elements to make them compatible with human capabilities and limitations. The results of the analysis describe how CA operations and functions should interface with the pilot to provide the necessary CA functionality to the UA-pilot system.

Requirements and guidelines for CA are partitioned into four categories: (1) General, (2) Alerting, (3) Guidance, and (4) Cockpit Display of Traffic Information.

Each requirement is stated and is supported with a rationale and associated reference(s).

3. Scope

3.1. Ground Rules

3.1.1. Requirements are based on Access 5 Program Collision Avoidance (CA) Work Package (WP) requirements and concepts as well as HSI standards and recommended practices.

3.1.2. Requirements defined are for the Access 5 program, Step 1, which limits scope to CA only for flight above FL430 and excludes requirements for coordinated maneuvers.

3.1.3. A Mode S transponder is installed in the ownship.

3.1.4. Requirements do not address: threats beyond the range setting for the traffic display; threats whose bearing information is lacking; threats equipped with Mode A or C transponders; evasive maneuver reversal requirements; evasive maneuver weakening or strengthening requirements

3.1.5. The magnitude of the pilot response in performing an evasive maneuver is determined by a combination of CA system requirements and aircraft performance limitations.

3.1.6. Domestic Reduced Vertical Separation Minima (RVSM) rules are not considered as part of the study.

3.1.7. As determined by CA system concept, the pilot may be required to determine an avoidance maneuver solely with reference to traffic targets on a display or may be required to act in response to a recommended evasive maneuver.

3.1.8. HSI Requirement Verification for dynamic operations (e.g., performance of an evasive maneuver) requires verification in a dynamic environment, i.e., simulation or flight test. HSI Requirement Verification for static operations (e.g., description of recommended evasive maneuvers) does not require verification in a dynamic environment, e.g., to be verified by analysis.

3.1.9. Requirements defined are independent of any design solution except those specified by the CA WP.

3.1.10. Pilot use of a CA system does not diminish pilot authority and responsibility for safe flight and compliance with Federal Aviation Regulations (FARs).

3.1.11. Although Access 5 does not employ the TCAS II, version 7 design, some of the human performance data produced in the development of that system represent reasonable and valid descriptions of HSI guidelines.

3.2. Assumptions

3.2.1. The CA system may not handle all situations.

3.2.2. The pilot will not make abrupt maneuvers that defeat CA system's recommended evasive maneuvers.

3.2.3. The pilot will not deviate from the assigned air traffic control clearance or flight plan based on pilot observation of displayed traffic. The pilot may deviate only in response to an identified threat for which an evasive maneuver is required for collision avoidance.

3.2.4. When the pilot deviates from the assigned air traffic control clearance or flight plan, in response to an identified threat for which an evasive maneuver is required for collision avoidance, and the pilot has the responsibility to determine the maneuver, the pilot will adhere to applicable FARs for right-of-way.

3.2.5. In the process of providing separation assurance, the collision avoidance system may induce a near midair collision (NMAC) on rare occasions.

3.2.6. CA system operation is normal, all modes are fully-operational, no inhibits are active, and there are no partial failures.

3.2.7. The pilot will have all necessary control and display capabilities in the Aircraft Control Station (ACS) to satisfy HSI requirements.

3.2.8. Pilot reaction time to a threat alert is five seconds.

4. Method

Research and documentation of human capabilities and limitations known for CA was performed through a review of HSI requirements documents, standards, and recommended practices.

Sources examined include Society of Automotive Engineers Aerospace Recommended Practices and Aerospace Resource Documents; FAA regulatory and advisory material; FAA Human Factors Design Guide; other key research papers.

The technology concepts in use by the CA WP were assessed. These include a plan view map display that depicts the ownship and proximate traffic icons; a vertical speed indicator that provides avoidance maneuver command information to the pilot; and an aural alerting system.

For these CA technology elements, HSI requirements for the interface to the pilot (in the form of pilot information and control requirements) were identified. Fundamentally, these requirements provide the candidate technology concepts with the necessary human-related elements to make them compatible with human capabilities and limitations.

Program documents were also used as reference material.[1]

5. Technology Interface Requirements

The HSI FRD describes the highest level functional requirement for communication as follows: "The Human System Interface shall convey information to the pilot to avoid cooperative aircraft."[2] Technology interface requirements in this document fall under this requirement.

Technology interface requirements are a necessary element of the HSI functional decomposition analysis of CA Functional and Performance requirements. The results of the analysis describe how CA operations and functions should interface with the pilot to provide the necessary CA functionality to the UA-pilot system.

They represent high-level, requirements for (1) pilot control of a CA system and (2) information required by the pilot to understand vehicle operation.

Requirements and guidelines are partitioned into four categories: (1) General, describing overarching pilot information and control

[1] Cooperative Collision Avoidance Functional Requirements for Step 1 – HALE UAS Flight Above FL430, Revision 3. 28 April 2005.
Step 1: Functional Requirements Document, Preliminary Draft. May 2005

[2] Step 1: Human System Integration (HSI) Functional Requirements Document (FRD), Version 1.1,July 2005.

requirements to the CA technology; (2) Alerting, the display function that warns the pilot of a change in system status and/or action to be performed; (3) Guidance, the display function that provides a directive to the pilot to perform a specific CA-related action; and (4) Cockpit display of traffic information, the generic display function that depicts traffic on a ACS display in relation to the ownship.

Each requirement is stated and is supported with a rationale and associated reference(s).

5.1. General

5.1.1. Information Required by the Pilot (Display Requirement).

The information provided by the system should enable the pilot to perform conflict resolutions, or respond to resolution guidance, in a timely manner.

5.1.1.1. Rationale.

The system should generate a sense of confidence in the pilot that the pilot is seeing all of the traffic relevant to performing these resolution responses, or that the system is considering, in generating resolution guidance. Otherwise, responses may be tentative and delayed, or competing resolutions may appear better suited to the conflict. As a general statement, the information provided by the system should enable the pilot to respond in an appropriate and timely manner and should not promote incorrect or unproductive response patterns. At the same time, the pilot shall use information describing traffic according to requirements established for the design and shall not employ the design for purposes other than those for which it was intended (e.g., TCAS traffic displays shall not be used by the pilot for traffic separation)[3].

5.1.2. Avoid Traffic by Maneuvering the UA (Control Requirement).

The pilot shall maneuver the UA in response to CA system information in an appropriate and timely manner to avoid a collision.

5.1.2.1. Rationale.

Once the pilot recognizes the need to take avoidance action based on CA system information, an appropriate flight control response shall be made. The response shall consider the time available in which to respond, direction of required maneuver, maximum g's allowed or prescribed for the maneuver, and other aircraft performance limitations[4].

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[3] Human Interface Criteria for Cockpit Display of Traffic Information, Aerospace Recommended Practice (ARP) 5365. 1999, para. 5.5.1, 5.8.3, 5.14.5, 5.14.22, 6.1.

Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration. 2002, para. 5.1.5, 7.1.1.8.

Human Interface Criteria for Collision Avoidance Systems in Transport Aircraft, Aerospace Recommended Practice (ARP) 4153. Society of Automotive Engineers. 1988, para. 4i, 8.1.

[4] Step 1: Human System Integration (HSI) Functional Requirements Document (FRD), Version 1.1,July 2005.

5.2. Alerting

5.2.1. ACS Display of Separation Loss (Display Requirement).

Once a loss of separation has been detected or forecast, the system shall alert the pilot.

5.2.1.1. Rationale.

As the pilot will be involved in many ACS operations, it is not expected that the pilot will monitor the CA traffic display at all times. Humans are poor monitors over extended period of time. As a result, augmentation of pilot monitoring skill is required in the form of a master visual alert and/or aural alert to warn the pilot of a traffic situation[5] .

5.2.2. ACS Display of Visual Alerts (Display Requirement).

Visual alerts may be provided to warn the pilot that a response to traffic is required.

5.2.2.1. Rationale.

Visual displays may serve to provide the pilot with alerts, which serve to direct the pilot's attention to some element of the traffic situation. The alerting displays may be integrated with a spatial presentation of the traffic[6].

5.2.3. ACS Display of Aural Alerts (Display Requirement).

Aural alerts may be provided to warn the pilot that a response to traffic is required.

5.2.3.1. Rationale.

Candidate CA concepts may use an aural (voice or tonal) display. This display may replace or supplement graphical displays. Both basic state information about other aircraft and warnings/alerts may be provided[7].

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[5] Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration. 2002, para. 7.1.1.1.

Human Interface Criteria for Collision Avoidance Systems in Transport Aircraft, Aerospace Recommended Practice (ARP) 4153. Society of Automotive Engineers. 1988, para. 4a.

[6] Human Interface Criteria for Cockpit Display of Traffic Information, Aerospace Recommended Practice (ARP) 5365. 1999, para. 7.1.2, 7.1.11.

Human Interface Criteria for Collision Avoidance Systems in Transport Aircraft, Aerospace Recommended Practice (ARP) 4153. Society of Automotive Engineers. 1988, para. 4a, 8.1, 8.3.

[7] Human Interface Criteria for Cockpit Display of Traffic Information, Aerospace Recommended Practice (ARP) 5365. 1999, para. 7.1.3.

Human Interface Criteria for Collision Avoidance Systems in Transport Aircraft, Aerospace Recommended Practice (ARP) 4153. Society of Automotive Engineers. 1988, para. 4b, 4a, 8.1.

Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration. 2002, para. 7.1.2., 7.1.2.10, 7.2.3, 7.2.4, 7.3.1, sect. 7.2.

5.2.4. ACS Message Urgency (Display Requirement). Based on system ability to determine the urgency of a traffic situation, alerts shall be presented to the pilot that describe the level of urgency in an unambiguous manner. Different alerts shall be provided for alerts with different urgencies.

5.2.4.1. Rationale. The urgency of the loss of separation or a traffic conflict situation is usually determined by the amount of time that the pilot has to respond to the situation. The less time the flight pilot has to respond, the more the system should help in determining what response should be made. These time constraints have an influence on how the system is used, especially at the most urgent levels. The system should provide enough information to ensure traffic awareness by the pilot in time for the pilot to respond by maneuvering the aircraft to achieve the necessary traffic separation. The assumption that should be made when designing a system around a very short pilot response time is that a portion of the system will have to be executive in nature (tell the pilot what response to make and expect the pilot to make it). The system should be designed to minimize the occurrence of situations requiring very short response times[8].

5.2.5. ACS Alert Integration (Display Requirement). Alerts annunciated to the pilot shall correspond to the presentation of traffic information (on displays) to the pilot and/or command information presented (visually or aurally) to the pilot.

5.2.5.1. Rationale. To ensure that the pilot understands that the annunciated alert applies to a specific target, the target shall be represented in such a way that it indicates itself as the subject of the annunciation[9].

[8] Human Interface Criteria for Cockpit Display of Traffic Information, Aerospace Recommended Practice (ARP) 5365. 1999, para. 4.2, 6.2.

Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration. 2002, para. 7.1.1.3.

Human Interface Criteria for Collision Avoidance Systems in Transport Aircraft, Aerospace Recommended Practice (ARP) 4153. Society of Automotive Engineers. 1988, para. 6.2, 8.2, 8.3.

[9] Human Interface Criteria for Cockpit Display of Traffic Information, Aerospace Recommended Practice (ARP) 5365. 1999, para. 4.2, 8.3.1.

5.2.6. Pilot Response Time to Alerts (Display Requirement). For a time-critical escape maneuver, the essential information elements of the first repetition of the alert message shall be conveyed within TBD s. If during the course of the escape maneuver a change (e.g., an increase in the severity of the maneuver or going from a vertical to a horizontal maneuver) becomes necessary, the essential elements of the alert shall be conveyed within TBD s.

5.2.6.1. Rationale. Pilot reaction times need to be developed based on collision avoidance geometries, response times of aircraft, and aircraft g-potential. TCAS II version 7 has developed pilot response time values, which may be used as an initial guide here, for line-of-sight operations[10].

5.2.7. ACS Nuisance Alerts (Display Requirement). Nuisance alerts (that is, conflicts caused by or resolved by normal operations such as leveling at assigned altitudes) that generate time critical warnings shall be minimized.

5.2.7.1. Rationale. The effect of nuisance alerts on the pilot is dependent on the urgency of the alert and the expected flight pilot response to the alert. The criteria to minimize nuisance alerts should be based on the number of nuisance alerts per flight hours as well as the ratio of nuisance to real alerts.[11]

5.2.8. ACS False Alerts (Display Requirement). The number of false alerts shall be minimized.

5.2.8.1. Rationale. The number of false alerts has a direct influence on the usefulness of the system because they affect the pilot's perception of and confidence in the information that the system presents. A high percentage of false alerts will diminish pilot confidence, result in non-compliance with appropriate

[10] Human Interface Criteria for Collision Avoidance Systems in Transport Aircraft, Aerospace Recommended Practice (ARP) 4153. Society of Automotive Engineers. 1988, para. 4i.

[11] Human Interface Criteria for Cockpit Display of Traffic Information, Aerospace Recommended Practice (ARP) 5365. 1999, para. 6.3.1.

Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration. 2002, para. 5.8.2, 5.8.3, 5.9.1.

Human Interface Criteria for Collision Avoidance Systems in Transport Aircraft, Aerospace Recommended Practice (ARP) 4153. Society of Automotive Engineers. 1988, para. 4e.

procedures, and produce an unacceptably-high percentage of NMACs).[12]

5.2.9. Pilot Response as a Cause of Conflict Propagation (Control Requirement). Appropriate pilot response to any level of alert shall prevent the conflict from transitioning to a situation of higher urgency.

5.2.9.1. Rationale. The design of the CA system, including its interface to the pilot at the ACS, should provide a necessary and timely response to traffic. In addition, the contribution of the time delay produced by the pilot should not be so long as to allow escalation of the initial traffic threat. Such escalations reduce the margin for safety and may lead to NMACs[13].

5.2.10. ACS Display of Operational Status (Display Requirement). Any failure or degradation of the system shall be detected and communicated to the pilot.

5.2.10.1. Rationale. As the pilot will be involved in many ACS operations, it is not expected that the pilot will monitor the CA system at all times. Humans are poor monitors over extended period of time. As a result, augmentation of pilot monitoring skill is required in the form of a master visual alert and/or aural alert to inform the pilot of a change in system operational status[14].

5.2.11. ACS Display of Mode Annunciations (Display Requirement). The operating mode of the system shall be clearly indicated to the pilot. All mode changes shall be emphasized to aid the pilot in determining that a mode change has occurred.

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[12] Human Interface Criteria for Cockpit Display of Traffic Information, Aerospace Recommended Practice (ARP) 5365. 1999, para. 6.3.

Human Interface Criteria for Collision Avoidance Systems in Transport Aircraft, Aerospace Recommended Practice (ARP) 4153. Society of Automotive Engineers. 1988, para. 4e.

[13] Human Interface Criteria for Cockpit Display of Traffic Information, Aerospace Recommended Practice (ARP) 5365. 1999, para. 4.3.

Human Interface Criteria for Collision Avoidance Systems in Transport Aircraft, Aerospace Recommended Practice (ARP) 4153. Society of Automotive Engineers. 1988, para. 4b, 4f, 4i, 4a, 4c, 4d, 8.1.

[14] Human Interface Criteria for Cockpit Display of Traffic Information, Aerospace Recommended Practice (ARP) 5365. 1999, para. 4.5, 9.1.1.7.

Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration. 2002, para. 5.8.2, 5.1.16, 5.3.3, 5.3.4, 5.5.7, sect. 5.6, 5.7.

5.2.11.1. Rationale. So the pilot understands the capabilities and limitations of the current state of the CA system, its modes shall be displayed to the pilot[15].

5.3. Guidance

5.3.1. Need (Display Requirement). Guidance is required and shall be displayed to direct the pilot to make the appropriate response.

5.3.1.1. Rationale. The assumption that should be made when designing a system that includes very short pilot response times is that a portion of the system will have to be executive in nature (tell the pilot what response to make and expect it to be made). This is because the pilot may not have time to perceive traffic information, determine the appropriate course of action, and affect a response in time. In addition, pilot performance in using a plan view display, e.g., Navigation Display or CDTI, that depict traffic data, has shown that pilot avoidance of traffic solely based on observation of targets is not satisfactory (see Figure 2). As the presentation of traffic does not appear in the same manner on an ATC display and airborne traffic-type display, many in-flight events have occurred where the pilot has taken incorrect action causing NMACs.[16]

[15] Human Interface Criteria for Cockpit Display of Traffic Information, Aerospace Recommended Practice (ARP) 5365. 1999, para. 8.3.1.

Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration. 2002, para. 5.8.2, 5.1.16, 5.3.3, 5.3.4, 5.5.7, sect. 5.6, 5.7.

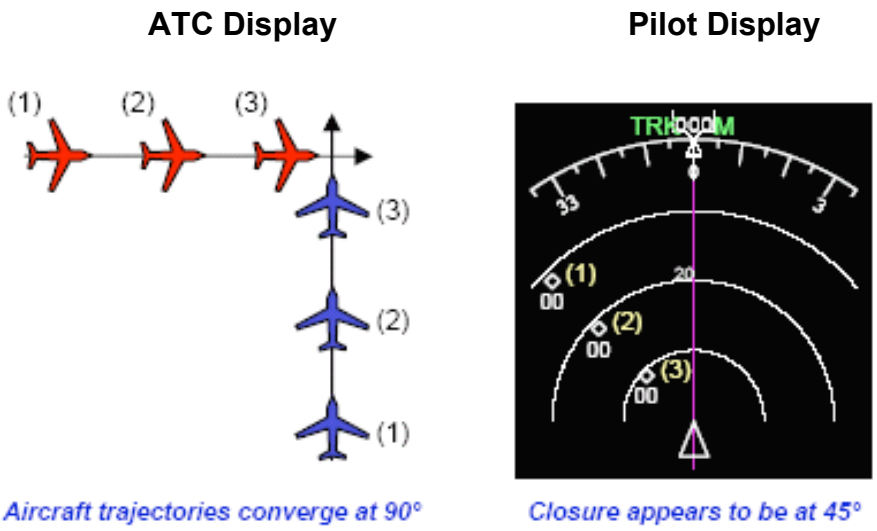
[16] Human Interface Criteria for Cockpit Display of Traffic Information, Aerospace Recommended Practice (ARP) 5365. 1999, para. 6.2.

Johnson, W., Bilimoria, K.., Thomas, L., Lee, H., and Battiste, V. Comparison of Pilot and Automation Generated Conflict Resolutions. Paper No. AIAA 2003-5400. AIAA Guidance, Navigation, and Control Conference and Exhibit. Austin, TX, August, 2003.

Eurocontrol, ACAS II BULLETIN No. 6. March, 2005.

Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration. 2002, para. 5.1.23, 5.3.2, 5.5.7, 5.14.1, 5.14.5, 5.14.6.

Human Interface Criteria for Collision Avoidance Systems in Transport Aircraft, Aerospace Recommended Practice (ARP) 4153. Society of Automotive Engineers. 1988, para. 4b, 41, 4c.



(Figure from **Eurocontrol, ACAS II BULLETIN No. 6)**

Figure 2. Differences in appearance of identical traffic situation on ATC radar display and flight deck TCAS display.

5.3.2. ACS Display of Guidance Information Content (Display Requirement). When guidance information is employed, the pilot shall have a clear understanding of the action to perform to resolve the conflict

5.3.2.1. Rationale. To ensure that the appropriate avoidance response is made, especially when the time to respond is short, information conveyed to the pilot shall make clear the nature and time-criticality of the response. When a conflict is detected and an alert is issued, additional resolution information may be needed. This may be in the form of a caution (e.g., "Traffic"), an open-loop command (e.g., "Climb"), or closed-loop command guidance (e.g., "Flight Director Bars"). The pilot should have a clear idea of what action to perform to resolve the conflict[17].

5.3.3. ACS Display of Removal of Guidance Information (Display Requirement). The command guidance shall be removed as soon as the alert condition no longer exists.

5.3.3.1. Rationale. To ensure that an inappropriate avoidance response is not made after traffic is clear, and to avoid generation of an unintentional traffic conflict, information conveyed to the pilot shall make clear when traffic is no longer a factor[18].

5.4. Cockpit Display of Traffic Information

5.4.1. General Concept Requirement (Display Requirement). The display format and information content shall be dependent on the intended use and operation of the CDTI.

5.4.1.1. Rationale. Each CDTI CA format has benefits and limitations. The pilot's assessment of the traffic situation and required actions have been found to be highly dependent upon the type of display[19].

[17] Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration. 2002, para. 5.1.23, 5.3.2, 5.5.7, 5.14.1, 5.14.5, 5.14.6.

[18] Human Interface Criteria for Collision Avoidance Systems in Transport Aircraft, Aerospace Recommended Practice (ARP) 4153. Society of Automotive Engineers. 1988, para. 8.8.8.3.

[19] Human Interface Criteria for Cockpit Display of Traffic Information, Aerospace Recommended Practice (ARP) 5365. 1999, para. 8.3.1.

Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration. 2002, para. 5.1.9, 5.1.15, 5.11, 5.14.6, 5.14.13, 5.14.22

5.4.2. ACS Display of Pilot-Requested Information (Display Requirement). In addition to an alerting function, the system shall have a function that allows the pilot to obtain more detailed information about the traffic situation.

5.4.2.1. Rationale. This information can be separated into Traffic Awareness and Traffic Avoidance categories. Traffic Awareness: The system shall enhance the pilot's traffic awareness by allowing a view of relevant airspace/traffic geometry information. In order to accomplish this, the aircraft's location (in all appropriate dimensions) relative to traffic shall be displayed. The pilot shall be provided sufficient information to accurately anticipate conflict situations. Traffic Avoidance: When a conflict is detected and an alert is issued, additional resolution information may be needed. This may be in the form of a caution (e.g., "Traffic"), an open-loop command (e.g., "Climb"), or closed-loop command guidance (e.g., "Flight Director Bars"). The pilot shall be presented with information that can provide a clear idea of what action to perform to resolve the conflict.[20].

6. Future Work

6.1. Step 1 Lower Level Information and Control Requirements.

The requirements described in this document represent a high level definition for pilot information and control capability. Future work is required to continue this analysis to the level appropriate to the needs of the program and its customers, (e.g., the FAA). Lower level information and control requirements will provide the FAA and manufacturers with an appropriate level of guidance without restricting the flexibility of design. The level of detail required is exemplified in FAR 23.777, "Means must be provided to indicate to the flight crew the tank or function selected." For Access 5 purposes, an analogous information requirement would read, "(For the top-level, Aviate functional requirement) A means must be

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Human Interface Criteria for Collision Avoidance Systems in Transport Aircraft, Aerospace Recommended Practice (ARP) 4153. Society of Automotive Engineers. 1988, para. 41, 8.1, 8.3.

[20] Human Interface Criteria for Cockpit Display of Traffic Information, Aerospace Recommended Practice (ARP) 5365. 1999, para. 4.4.

Human Interface Criteria for Collision Avoidance Systems in Transport Aircraft, Aerospace Recommended Practice (ARP) 4153. Society of Automotive Engineers. 1988, para. 4a, 4b, 4i, 4c, 4d, 8.1, 8.3.

provided at the ACS to indicate to the pilot the tank or function selected." Once this level of detail is developed for each top-level functional requirement, the information and control requirements definition effort for Step 1 will be complete.

6.2. Step 2, 3, and 4 Information and Control Requirements.

After work for Step 1 has been completed, information and control requirements analyses are necessary for the succeeding Steps. The analysis will follow the functional requirements developed for these Steps and will focus on phases from takeoff to cruise and from cruise to landing. The analysis for altitudes between approximately FL180 and FL430 will require only minor additions to Step 1 results. Significantly new information will be produced from this analysis for the critical takeoff, climb, approach, and landing phases.

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